The Lack of Ultraluminous X-ray Sources (ULXS) in Early-type Galaxies

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Ultraluminous X-ray Sources (ULXs)

- Discovered in the *Einstein* era (Fabbiano 1989).
- Have X-ray luminosities of 10^{39} - 10^{41} ergs s^{-1}.
- NOT located in the nucleus of the host galaxy.
- Variability studies have shown that most ULXs are composed of some type of accreting compact object.

$$L_{Eddington} = \frac{4\pi c G M m_p}{\sigma_T} = 1.3 \text{ x } 10^{38} \frac{M}{M_{Sun}} \text{ ergs s}^{-1}$$

For a 1.4 M_{sun} neutron star, $L_{Eddington}$ = 1.8 x 10^{38} ergs s^{-1}

For a 15 M_{sun} black hole, $L_{Eddington}$ = ~2 x 10^{39} ergs s^{-1}

How are X-ray luminosities of up to 10^{41} ergs s^{-1} achieved?

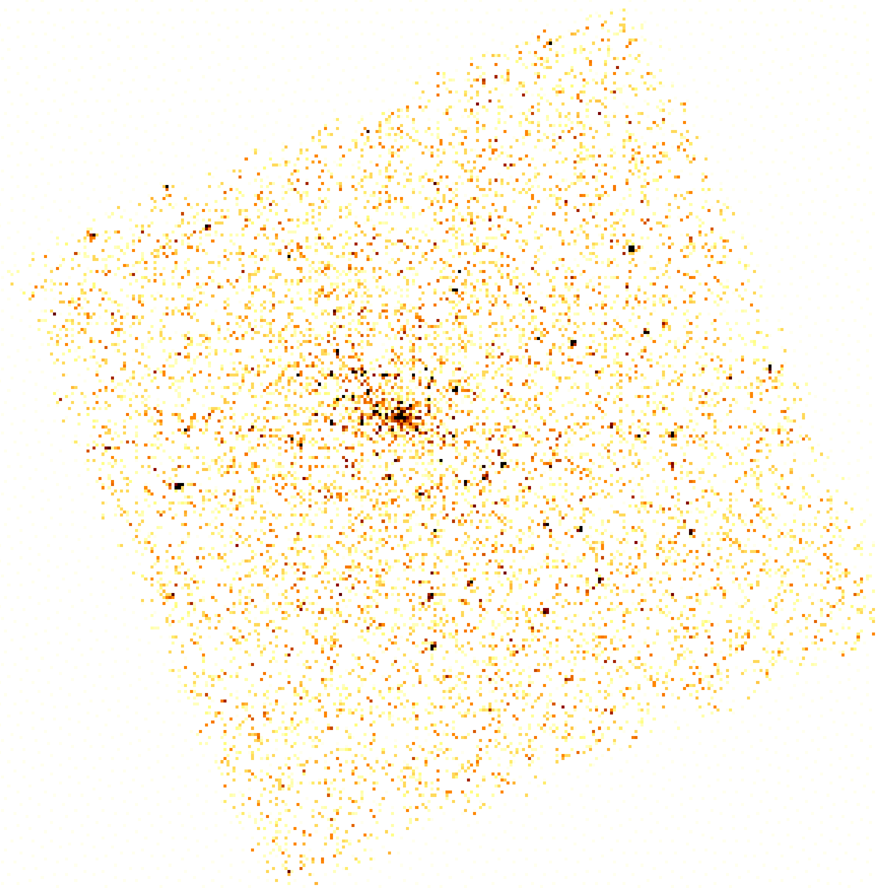
Possible Explanations For ULXs

1) Intermediate mass black holes (IMBHs):
   - a 50-1000 M_{sun} black hole accreting near its Eddington limit (Colbert & Mushotzky 1999)
   - would represent the "missing link" between stellar mass black holes and supermassive black holes
   - difficult to create a black hole of this mass

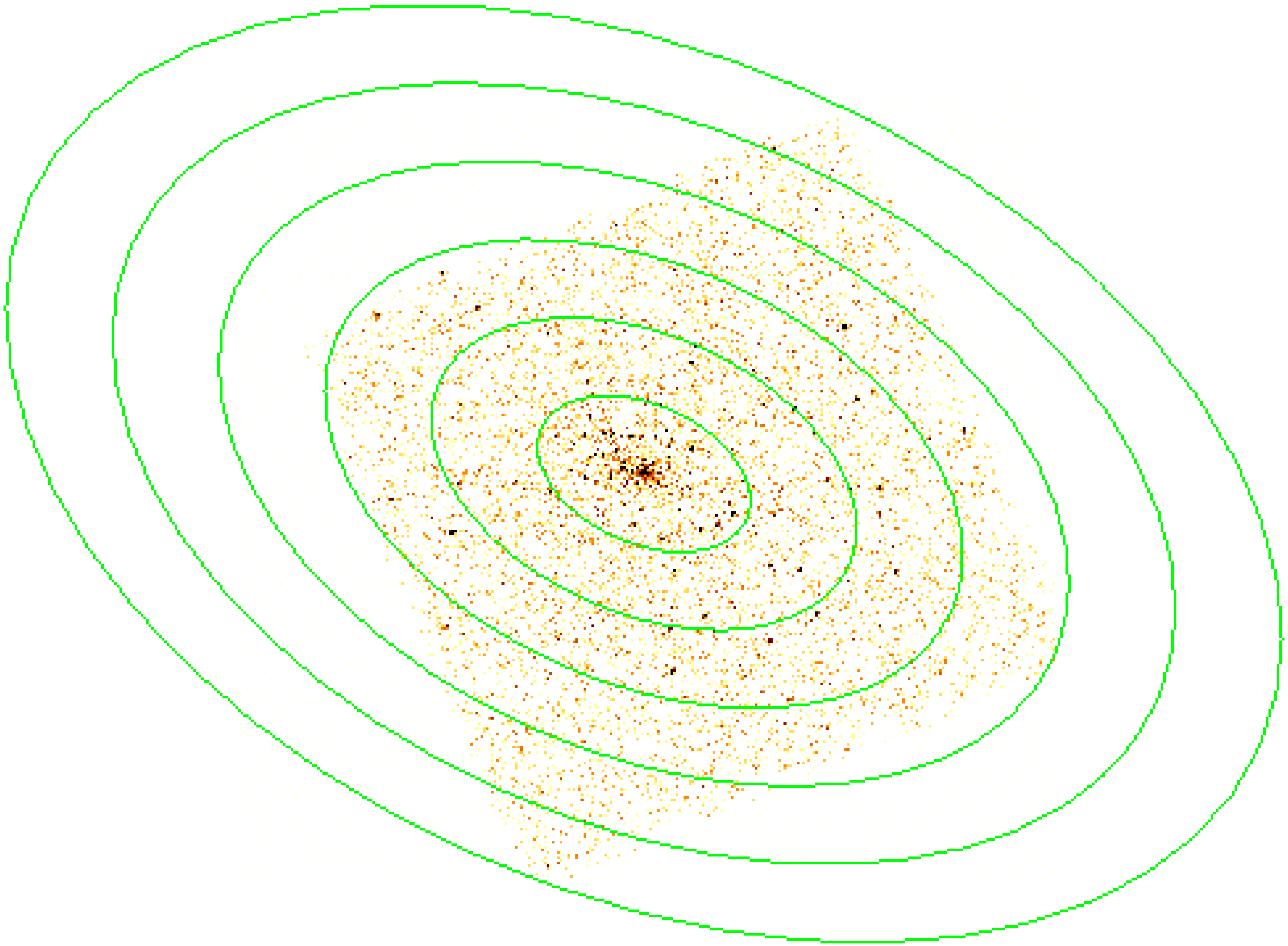
2) Beamed or anisotropic X-ray emission from a stellar mass black hole:
   - thermal-timescale mass transfer onto a stellar mass black hole (King et al. 2001)
   - requires an intermediate-to-high mass donor star
   - difficult to explain ULXs in old stellar populations

The Chandra Sample and Analysis

- 27 galaxies observed with the Chandra ACIS-S chip (Es and S0s).
- Only galaxies within 35 Mpc were considered so that $>10^{39}$ ergs s^{-1} sources contained at least 40 counts to avoid incompleteness.
- $\Gamma = 2.0$ power law model used to convert counts to energy flux.
- All X-ray luminosities computed in the 0.3-10 keV energy range.
- The position of each $> 10^{39}$ ergs s^{-1} source was noted (e.g., between 0-1 effective radii, 1-2 effective radii…)

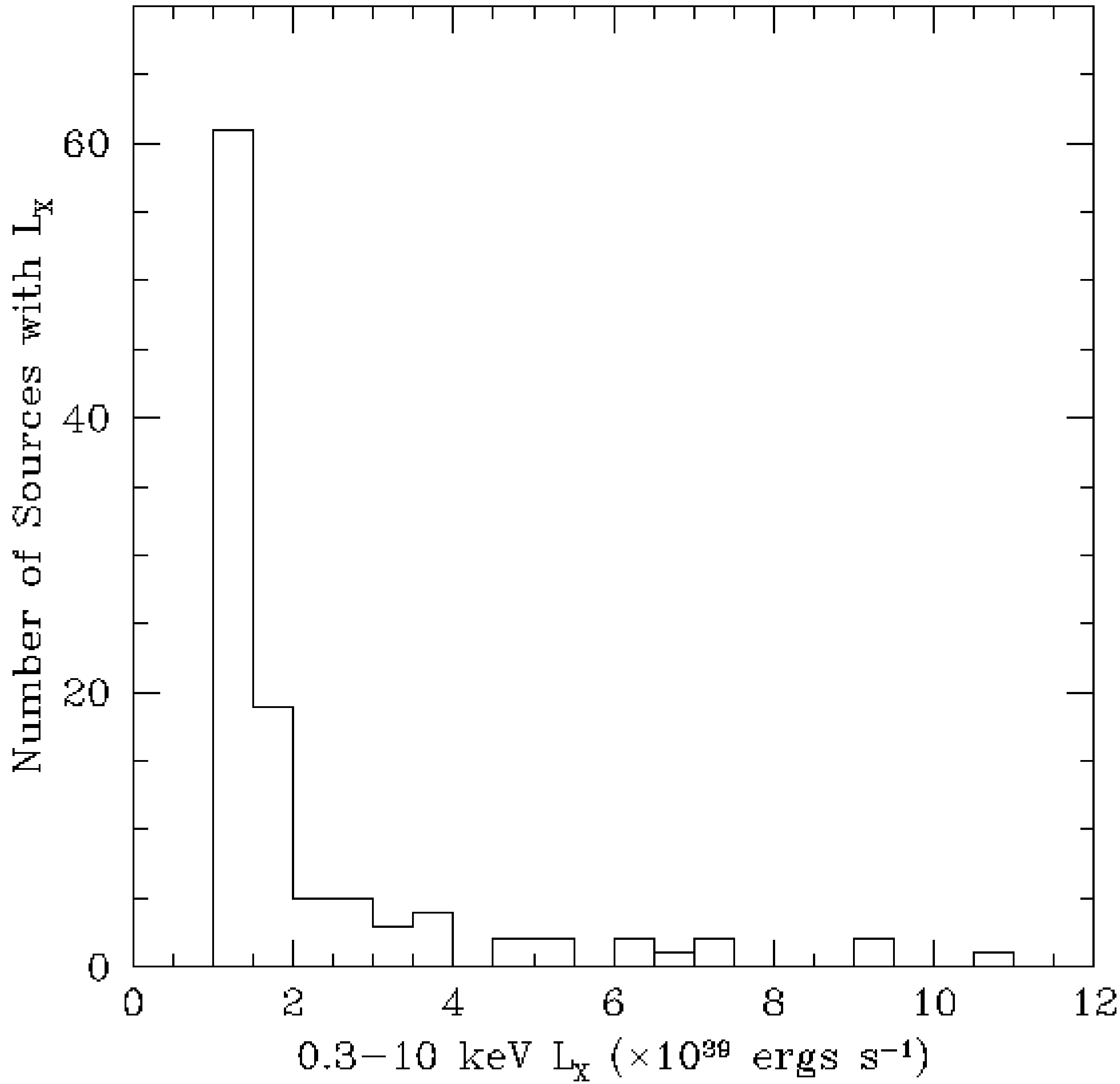


NGC4697 - Chandra ACIS-S



NGC4697 - Chandra ACIS-S

Luminosity Function of $>10^{39}$ ergs s^{-1} Sources For All 27 Galaxies



Expected Number of Unrelated Foreground/Background Sources

Use ROSAT HRI Log N vs. Log S_X from Hasinger et al. (1998):

$N(>S_X) = 110.0\ S_X^{-1.94}$	$S_X < 2.66 \times 10^{-14}$ ergs s^{-1} cm^{-2}
$= 238.1\ S_X^{-2.72}$	$10^{-13} < S_X < 2.66 \times 10^{-14}$ ergs s^{-1} cm^{-2}
$= 91.0\ S_X^{-2.3}$	$S_X > 10^{-13}$ ergs s^{-1} cm^{-2}

	1-2 x 10^{39} ergs s^{-1}	> 2 x 10^{39} erg s^{-1}
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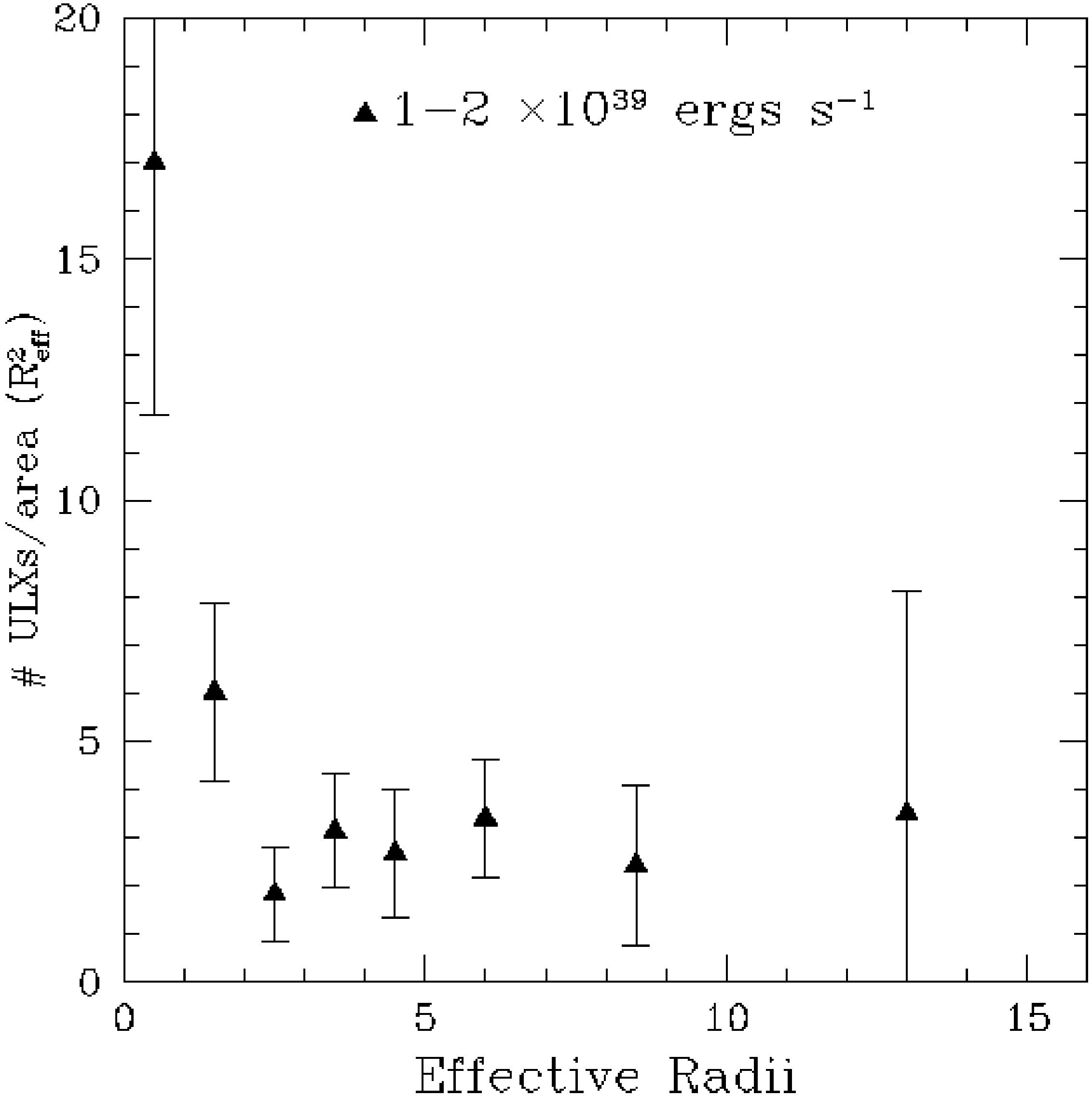
	$1\text{-}2 \times 10^{39}$ ergs s^{-1}	$> 2 \times 10^{39}$ erg s^{-1}
Number of Sources Expected	66.5	23.2
Number of Sources Detected	80	29

Radial profile of

1-2 x 10^{39} ergs s^{-1}

sources, normalized by area.



Radial profile of

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Radial profile of

> 2 x 10^{39} ergs s^{-1}

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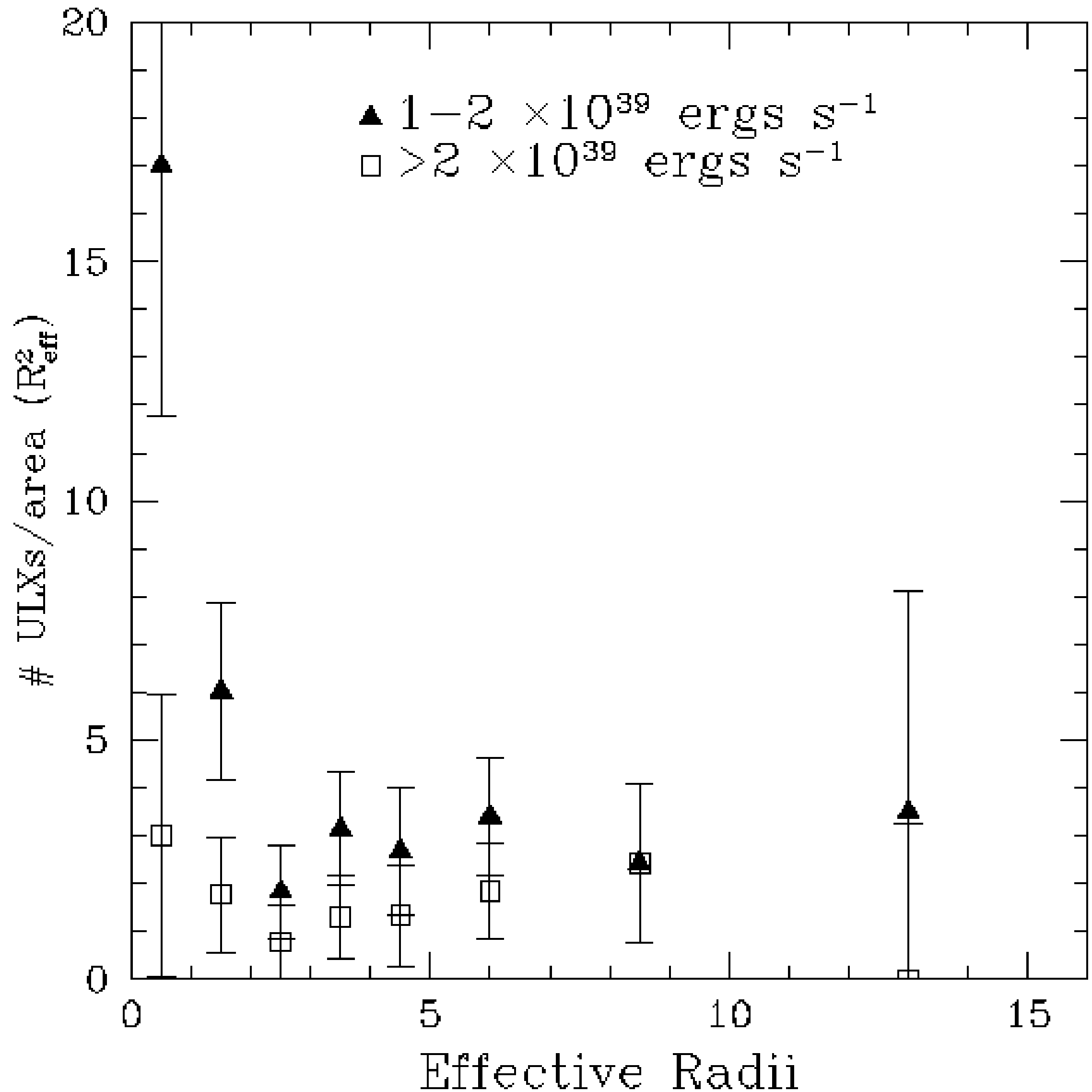

Colbert and Ptak (2002) ULX Catalog

Colbert and Ptak (2002) found 87 ULX candidates within 15 early-type and 39 late-type galaxies with the ROSAT HRI.

Some overlap with our sample, and in general extended to larger radii than our sample (out to twice the R_{25} contour).

Assumed a $\Gamma = 1.7$ spectral model, and quoted 2-10 keV X-ray luminosities ⇒ L_X (2-10 keV) = 0.5 * L_X (0.3-10 keV)

Lower limit of Colbert & Ptak (2002) catalog:
L_X (0.3-10 keV) = 2×10^{39} ergs s^{-1}, so we expect their spatial distribution to be consistent with being randomly distributed for ULXs in early-type galaxies.

Spatial Distribution: Early- vs. Late-Type

Colbert & Ptak (2002) ULXs were divided into 4 radial bins:

	0-0.5 R_{25}	0.5-1.0 R_{25}	1.0-1.5 R_{25}	1.5-2.0 R_{25}
Random Distribution	1	3	5	7

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Galaxies with T-type > -2.0	22	17	7	6

Two ULXs in Globular Clusters of NGC1399

Two $L_X > 2 \times 10^{39}$ ergs s^{-1} sources were found within globular clusters of NGC1399 (Angelini et al. 2001).

Source 1: $L_X = 2.3 \times 10^{39}$ ergs s^{-1} (for $d = 20$ Mpc)

Source 2: $L_X = 4.7 \times 10^{39}$ ergs s^{-1}

Explanations:

1) Globular cluster is a miss-identified background AGN.

2) Globular clusters are capable of hosting ULXs (although very rarely).

Propose a "Standard" Definition for a ULX

Various studies have defined ULXs differently, using different luminosity thresholds and different energy bands.

X-ray sources that have X-ray luminosities of $1\text{-}2 \times 10^{39}$ ergs s^{-1} aren't really "ultraluminous", as they can be adequately explained by accretion onto a ~10-20 M_{sun} black hole.

2×10^{39} ergs s^{-1} seems to provide a good break between ULXs and normal X-ray binaries:

- more exotic explanation required (IMBH or beaming)
- more luminous sources lacking in old stellar populations

→ A ULX has L_X (0.3-10 keV) > 2×10^{39} ergs s^{-1}

Summary

1) A sample of 27 galaxies observed with Chandra has revealed that X-ray sources more luminous than 2×10^{39} ergs s^{-1} are absent from early-type galaxies, or at least very rare.

2) Both the number and spatial distribution of X-ray sources with X-ray fluxes corresponding to luminosities $> 2 \times 10^{39}$ ergs s^{-1} are consistent with what is expected from a random distribution (not the case for spiral galaxies).

3) Propose that ULXs be defined as non-nuclear X-ray sources having L_X (0.3-10 keV) $> 2 \times 10^{39}$ ergs s^{-1} .